STUDIES ON THE ADSORPTION OF $^{125}$I ON METALLIC PELLETS FOR THEIR POTENTIAL APPLICATION IN BONE DENSITOMETRY FOR THE DIAGNOSIS OF OSTEOPOROSIS

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Abstract

$^{125}$I - bone densitometry sources find extensive application in the diagnosis of osteoporosis by using single photon absorption (SPA) technique. Silver pellets of size ~ 2.5 mm (l) x 0.6 mm (f) were developed as base matrix for adsorption of $^{125}$I. Determination of specific surface area and pore size analysis of plain silver and palladium coated silver pellets was carried out. Experimental conditions for quantitative adsorption of $^{125}$I were optimized and the sources containing upto ~ 1.48 GBq of $^{125}$I were prepared. The leachability of sources was found to be < 0.01%. Such $^{125}$I - bone densitometry sources developed at our end have potential of application in the diagnosis of osteoporosis after encapsulation of sources within titanium capsules.

Introduction

Osteoporosis is a condition in which the bones become porous and fragile due to the loss of bone matrix (Ca$^{2+}$ etc.), leading to the decrease in the density of bones. It is often seen in persons with impaired bone metabolism, particularly in women during post menopause stage. Osteoporosis is common in absence of medical intervention [1]. Measurement of bone density is a useful diagnostic parameter for treatment planning. Some of the established procedures for bone density measurement are Single Photon Absorptiometry (SPA), Dual Photon Absorptiometry (DPA), Quantitative Computerized Tomography (QCT), Dual Energy X-ray Absorptiometry (DEXA) and Ultrasonography. Among these, SPA is a precise and accurate quantitative method available for
the determination of bone density. This is based on the attenuation of a photon that is passed through the bone, where the degree of attenuation is proportional to the bone density. SPA technique uses photons from a single energy radioactive source. In most cases radioisotopes such as $^{125}$I or $^{241}$Am are used. The use of $^{125}$I is preferred over $^{241}$Am, on account of its relatively easy availability and low radiotoxicity.

In a typical SPA analysis, the extremity is scanned in a rectilinear fashion, and the intensity of the photon beam after passage of the body is registered by a scintillation detector. SPA is mainly used for bone mineral measurements of the forearm or in the lower extremities from the distal femur and below.[2-3]. Depending upon various conditions, the choice of technique to be used in bone densitometry is left with the clinicians. However, despite several developments, SPA technique is still used widely as it is very reliable, relatively inexpensive and precise. It also involves very low radiation exposure and many SPA units can be used even in private offices. Preparation of a very small source of $^{125}$I (pellet of size ~ 2.5 mm (φ) x 0.6 mm (l)) with uniform dose distribution is an intricate job. Techniques such as impregnation of $^{125}$I on charcoal beads, electrodeposition of $^{125}$I on metallic substrates, etc. have been employed by some manufacturers for the preparation of $^{125}$I- bone densitometry sources. In all these substrates, $^{125}$I is confined to a minimal area of the base matrix and point sources incorporated with $^{125}$I are encapsulated in titanium capsules of dimension ~ 3 mm (OD) x 10mm (l).

In the studies carried out at our end, metallic silver pellets of ~2.5 mm (φ) x 0.6 mm (l) were developed as a base matrix and conditions for the adsorption of $^{125}$I on plain silver pellets as well as on palladium coated silver pellets were optimized. The sources were coated with thin film of polystyrene as a protective barrier to reduce the spread of contamination during handling and encapsulation of sources.

**Materials**

Reducing agent free $^{125}$I was procured from M/s Institute of Izotop, Hungary. High purity silver powder having particle size of ~20-25 micron (φ) was procured locally. Silver pellets of required size were fabricated with the help of a hydraulic press located at AFD, BARC. Specific surface area and pore size determination was done with the help of ‘SORPTOMATIC-1990 Analyzer’, procured from M/s C.E. Instruments, Italy. The well type NaI (Tl) scintillation counter and well type re-entrant ion chamber were used for source activity measurements. Polystyrene beads of ~ 6 mm (φ) manufactured by M/s Fluka Chemicals were used for polymer coating of $^{125}$I- adsorbed pellets. All other chemicals used were of GR/AR grade procured from reputed manufacturers.

**Experimental**

*Fabrication of Metallic Pellets*

The fabrication of silver pellets of ~2.5 mm (φ) x 0.6 mm (l) was carried out through powder metallurgy route by ‘Cold Die Compaction Technique’. Silver powder of ~20-25 micron (φ) grain size was compressed at a moderate pressure of ~ 0.5 kg/cm$^2$ with the help of hydraulic press. A stroke controlled multiple hole cold die made from stainless steel was developed and employed to shape the silver powder in required pellet form and the stroke length was suitably adjusted to obtain silver pellets of ~ 0.6 mm (l).
Specific Surface Area and Porosity Determination

The specific surface area and pore size analysis of plain silver / palladium coated silver pellets was carried out by using ‘SORPTOMATIC 1990’ analyzer by studying adsorption- desorption isotherms. The lower part of the adsorption or desorption isotherm (i.e. $0.05 \leq \frac{P}{P_0} \leq 0.35$) was used for the measurement of specific surface area by multipoint B.E.T. Method [4]. The entire adsorption / desorption isotherm was used for pore size analysis. The pore volume and pore radius were calculated by considering the adsorbed film at the pore walls as cylindrical pores model [5].

Adsorption of $^{125}\text{I}$ on Metallic Pellets

The cleaned silver pellets were treated with 0.5% (w/v) PdCl$_2$ solution at $-100^\circ\text{C}$ for $-15$ min to coat them with palladium. Experimental conditions such as reaction volume, reaction temperature etc. were optimized for the quantitative adsorption of $^{125}\text{I}$ on both plain silver pellets as well as on palladium coated silver pellets. Initial tracer experiments were performed by adsorbing $-370$ KBg (10 mCi) of $^{125}\text{I}$ in the presence of $-30$ mg of carrier iodide (equivalent to $-18.9$ GBq) and later, the higher activity pellets were prepared under optimized conditions by using concentrated $^{125}\text{I}$ solution of radioactive concentration $-3.33 - 3.7$ GBq/mL. The activity associated with the pellets in tracer experiments was measured with the help of NaI (Tl) scintillation counter and that of having higher activity was measured by using a pre-calibrated re-entrant ionization chamber.

Leachability

The radioactive pellets were subjected to leachability test in accordance with a procedure prescribed by AERB [6]. Individual $^{125}\text{I}$-adsorbed pellets containing upto 1.48 GBq of $^{125}\text{I}$ were kept in 100 mL of still double distilled water at room temperature for 48 h. At the end of the test, the leached out activity was estimated by assaying the samples of leachant with the help of a NaI (Tl) scintillation counter of known efficiency.

Polymer Coating on Pellets Adsorbed with $^{125}\text{I}$

$^{125}\text{I}$ - adsorbed palladium coated silver pellets were coated with polystyrene by treating them for $-10$ seconds with polystyrene solution at a concentration of $-175$ mg/mL. Coated pellets were washed with luke warm water at $-30-35^\circ\text{C}$ after drying.

Results and Discussion

Silver pellets of required size could be fabricated with the help of a multiple hole cold compaction die set [Fig.1]. The specific surface area of plain silver pellets and palladium coated silver pellets as determined by B.E.T. Method was found to be 6.7 m$^2$/g and 6.8 m$^2$/g respectively. The pore volume for both the types of pellets was found to be $-0.003$ cc/g. Both these parameters (i.e. high surface area and low porosity) are highly favorable for optimum adsorption of $^{125}\text{I}$ on metallic substrates. The pore size distribution of both the types of pellets is shown in [Fig.2]. The shrinkage of pore size in case of palladium coated silver pellets may be attributed to the coating of palladium within the pores. The reaction temperature of $-60-70^\circ\text{C}$ and reaction time of $-6$ h were found to be optimum for the adsorption of $^{125}\text{I}$ in the presence of $-30$ mg of carrier iodide. Adsorption of $^{125}\text{I}$ was found to depend upon the reaction volume as shown in [Table 1]. It was observed that as the effective iodide concentration increases (reaction volume decreases), the percentage adsorption also increases. However, below a certain reaction volume, it was impractical to work with low volumes. More
than 75% adsorption of $^{125}\text{I}$ was obtained on both silver/palladium coated silver pellets, when the reaction volume was kept as ~250 µL. The sources could be coated with thin layer of polystyrene without appreciable radiation cut-off. The results of leachability test are depicted in [Table 2]. On account of lower leachability, palladium coated silver pellets were preferred over plain silver pellets as a base matrix for the adsorption of $^{125}\text{I}$. $^{125}\text{I}$ - sources upto ~1.48 GBq (40 mCi) of $^{125}\text{I}$ and containing ~30 mg of carrier iodide (equivalent to ~18.5 GBq of $^{125}\text{I}$ ) could be prepared by repeating two adsorption cycles.
Conclusion

A method for the adsorption of $^{125}$I on metallic pellets could be developed for the fabrication of $^{125}$I-bone densitometry sources for the diagnosis of osteoporosis. Silver pellets of required size could be fabricated and surface area and pore size determination was carried out. Conditions for adsorption of $^{125}$I on plain silver pellets as well as on palladium coated silver pellets could be optimized. Palladium coated silver pellets exhibited lower leachability (< 0.01%) and were used for preparation of sources up to the radioactive strength of ~1.48 GBq each.

The sources developed at our end have potential application in the diagnosis of osteoporosis. The encapsulation of sources within the titanium capsules of ~ 50 micron thin window is warranted for their deployment in the diagnosis of osteoporosis.

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References

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